Reference: *Biol. Bull.*, **160**: 1–10. (February, 1981)

SEASONAL DYNAMICS OF A LEECH-MYSID SHRIMP INTERACTION IN A TEMPERATE SALT MARSH

DENNIS M. ALLEN[1] AND WENDY B. ALLEN[1]

Dept. of Biology and The Wetlands Institute, Lehigh University, Bethlehem, PA 18015

Abstract

The spatial and temporal distributions and aspects of the life history of the marine leech, *Mysidobdella borealis*, were studied in a salt marsh embayment and adjacent ocean area in southern New Jersey, U. S. A. Mysid hosts, *Neomysis americana*, occurred in all epibenthic sled collections, but leeches were only collected in the embayment in winter and spring. Leeches were in the cooler ocean areas during the summer. The recurrence of *M. borealis* in the embayment in November or December coincided with the migration of large mysids from the ocean. Leeches reproduced in the marsh each spring, but no life stages were collected after embayment temperatures reached 20°C. Laboratory experiments demonstrated that adult and newly hatched *M. borealis* were killed by long exposures to temperatures greater than 20°C. The recruitment and survival of the boreal-arctic leech in estuaries at the southern extent of its geographical range is determined by host migration and water temperature.

Introduction

Marine leeches have been reported from a variety of vertebrate and invertebrate hosts, but relationships between the spatial and temporal distributions of leech and host populations are not well known. Leeches of the family Piscicolidae are most often associated with fishes, but invertebrates, especially crustaceans, also serve as at least temporary hosts (Meyer and Barden, 1955). Decapod crabs often are the substrates on which leeches deposit cocoons after leaving their primary fish hosts (Moore and Meyer, 1951; Daniels and Sawyer, 1975). Other crustacean hosts include decapod shrimps (Selensky, 1923), amphipods (Epshtein, 1959), isopods (Sawyer and White, 1969), and mysids (Selensky, 1927; Dukina *et al.*, 1974).

Burreson and Allen (1978) described the anatomy, geographical range, and some aspects of the biology of the marine leech *Mysidobdella borealis* (Johansson) in the western North Atlantic. This leech has been reported from three mysids, *Mysis oculata* (Fabricius) in arctic seas (Selensky, 1927; Vasileyev, 1939; Epshtein, 1961), and *Mysis stenolepis* Smith and *Neomysis americana* Smith on the east coast of North America (Burreson and Allen, 1978).

The only known host of *M. borealis* on the coast of southern New Jersey is *N. americana*. Extensive laboratory tests failed to identify alternative hosts and various observations indicated that the leech was an obligate parasite which fed on the mysid (Burreson and Allen, 1978). Leeches introduced into aquaria containing *N. americana* swam until they made contact with a mysid and then remained attached. Adult leeches only left their hosts to deposit cocoons on hard substrates, and juvenile

Received March 23, 1980; Accepted October 17, 1980.

Abbreviations: UB, upper embayment; LB, lower embayment.

[1] Present Address: Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Georgetown, SC 29440.

M. borealis attached to *N. americana* within hours of hatching (Burreson and Allen, 1978).

The intent of the present study was to determine the seasonal distribution, life history, and physiological tolerances of *M. borealis* near the southern extent of its range and to examine the relationship between the population dynamics of the leech and the population dynamics and distribution of the mysid host, *N. americana*.

Materials and Methods

Hereford Inlet (38°58′–39°06′ N, 74°44′–74°48′ W) includes a tidal embayment flanked on the east by a barrier island and on the west by extensive *Spartina alterniflora* Loisel marshes and shallow lagoons. Five sampling sites were along the major axis of tidal flow within the embayment and two were in the ocean (Fig. 1). Stations 1 and 2 had irregular mud bottoms (6–8 m) with accumulations of marsh detritus and macroalgae characteristic of the upper embayment (UB). Station 3 traversed a sandy basin (7–10 m) at the confluence of two major waterways. Stations 4 and 5 had rippled sand bottoms (5–8 m) typical of the current-scoured areas of the lower embayment (LB). Stations 6 and 7 were outside of the sand shoals at the mouth of Hereford Inlet and had flat sand bottoms (10–14 m) representative of the shallow ocean area.

Semidiurnal tides extend to the center of Great Sound (Fig. 1) and prevent vertical stratification of temperature, salinity, or dissolved oxygen in the embayment. Temperature gradients are established along the study transect during the spring and fall as a result of differential rates of change for the shallow sounds and coastal waters. Figure 2 shows the bottom water temperature curves for station 1 and 7 and demonstrates the lag in the warming of ocean waters during early summer. Little fresh water flows into Hereford Inlet and salinities remained 28–32‰ in the major waterways.

Leeches attached to their hosts, specimens of *N. americana*, were collected with an epibenthic sled designed to capture small organisms within 30 cm of the bottom. A rectangular steel frame (51 × 30 cm), which oriented the mouth of a #2 mesh (365 μ) Nytex net perpendicular to the bottom, was mounted on a horizontal frame which slid over the bottom on three skis. Preliminary studies demonstrated that towing the sled in the direction of the tidal current was the most effective way to collect mysids, which orient and swim into tidal currents near the bottom. Five-minute tows from a boat just making headway with the tidal current traversed approximately 100 m of bottom. Surface and bottom water temperatures and salinities were measured with an induction salinometer immediately after each tow.

The seasonal occurrence of *M. borealis* was determined from a series of 80 cruises between June 1975 and June 1977, in which at least stations 1–5 (Fig. 1) were sampled sequentially beginning at station 1 approximately 1.5 h after slack tide. Cruises were made at intervals of 7–10 days and a total of 424 collections taken. Each sample was preserved with buffered formalin immediately after collection. In the laboratory, the entire sample was usually enumerated, but collections which contained large volumes of detritus or organisms were split with a cylindrical plexiglass plankton splitter until a workable portion was obtained. All sorting and counting was done at 10.5× with a binocular zoom microscope.

Total numbers of *M. borealis* were recorded for each collection. Since preservative was added to the live samples in this series, the leeches were usually fixed in a twisted configuration, and total lengths could not be measured accurately. Leeches which were less than 3 mm were considered juveniles, those 3–5 mm were

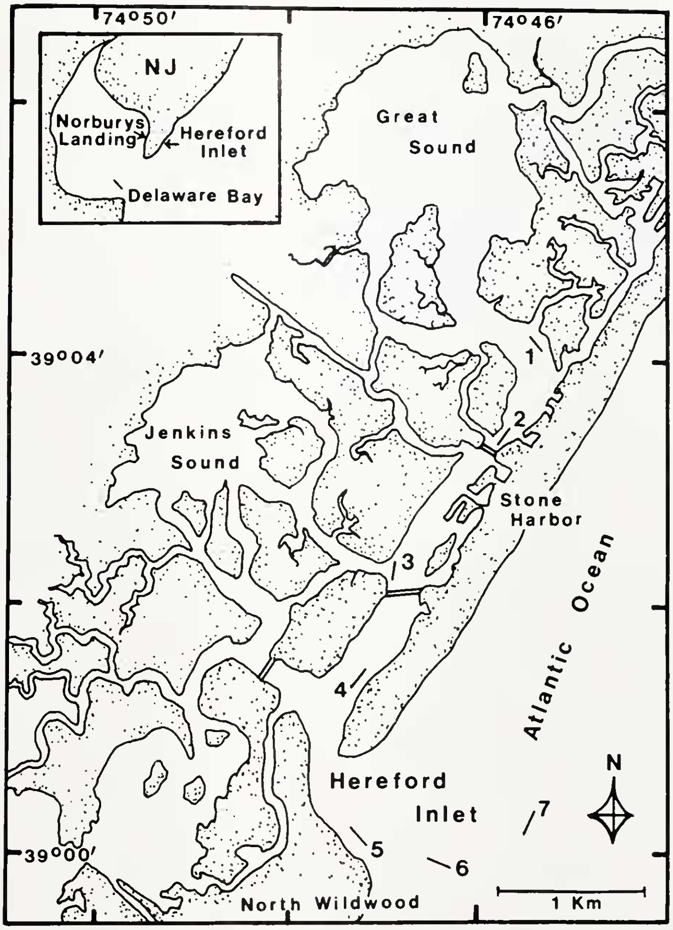

FIGURE 1. Location of sampling stations 1–7 at Hereford Inlet and Norburys Landing, New Jersey. Lines at the stations represent the orientations and approximate distances of sled tows.

small adults, and those larger than 5 mm were adults. Leeches collected in New Jersey waters were protandric and never exceeded 12 mm. Testisacs were partially atrophied in sectioned leeches over 7 mm in length, and the largest individuals possessed vestigal testisacs and mature ovisacs (Burreson and Allen, 1978).

The length frequency distribution of the leech population and the variability in the ratio of total numbers of leeches to total numbers of mysid hosts was determined in a series of consecutive tows at station 2 on four cruises. The collections were returned to the laboratory within an hour and most leeches remained swimming near the surface of the sample jar. All *M. borealis* were removed, then relaxed and straightened in dilute ethanol before being preserved in formalin. Leeches were measured to the nearest 0.1 mm with an ocular micrometer.

About 300 supplementary collections made with epibenthic sleds and plankton nets between March 1974 and June 1978 were also examined for *M. borealis*. These samples were usually taken in areas different from those in the regular sampling program in Hereford Inlet and included many night collections.

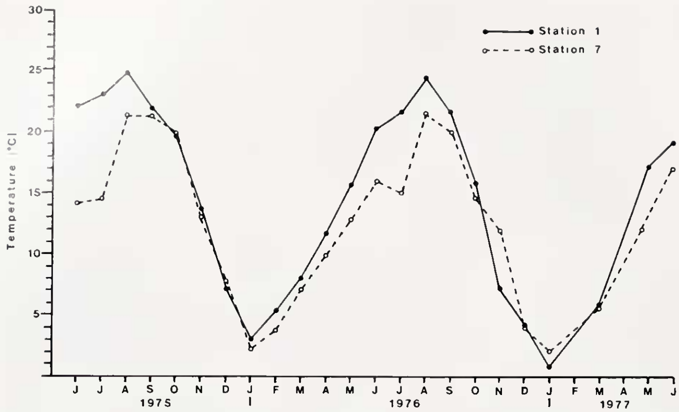

FIGURE 2. Mean monthly bottom water temperatures at UB station 1 and ocean station 7 from June 1975 to June 1977.

Collections were also made on the intertidal flats of Delaware Bay at Norburys Landing, New Jersey (Fig. 1). Samples were taken with hand-held sweep nets in shallow water every 1–3 days from late March to early June 1978. Salinities varied between 18 and 27‰ and temperatures from 4 to 22°C.

M. borealis specimens were maintained in a running sea water system from December through May each year. The swimming and attachment behavior of the leeches were observed. Small groups of leeches were isolated with mysid hosts in static aquaria at different temperatures for observations on reproduction and longevity.

Experiments were conducted to determine the temperature and salinity tolerances of *M. borealis*. Plastic containers, each with 350 ml of water at one of five salinities (0, 10, 15, 20, and 30‰) were placed into constant temperature baths and allowed to equilibrate for at least 12 h. Tests were run at six temperatures (0, 10, 15, 20, 22, and 25°C) and all temperature-salinity combinations were tested two or three times. Ten adult leeches and twelve mature *N. americana* were placed in each container without prior acclimation, and percentage survival was recorded each day for 10 days.

RESULTS

Mysidobdella borealis occurred in 120 of the 424 epibenthic sled collections made in the regular sampling program. The mysid host, *Neomysis americana*, was in all samples. Ratios of leeches to mysids greater than 1:100 were found in 20 of the 120 collections in which leeches occurred. The highest incidence was 9.7:100 on 21 March 1977, at station 1. The greatest number of leeches taken in a 5-min tow was 744 (with 16,648 mysids) on 26 December 1975.

The mean monthly values for numbers of *M. borealis* per 1000 *N. americana* (Table I) indicate that leeches were most abundant from December to March or April. Leeches were seldom collected within the embayment during the summer or fall, even though *N. americana* was most abundant in the study area from June to October (Allen, 1978). Juvenile *M. borealis* were occasionally collected at the LB stations in July and August 1975; however, small leeches (3–5 mm) were consistently collected during this period at the ocean stations where water temperatures remained near 15°C. No leeches were collected at any station from mid-

August to mid-December 1975, and only a few individuals occurred at the ocean stations from early August to mid-November 1976 (Table I).

The recurrence of leeches in the study area each winter was first detected at the ocean stations. During the following weeks abrupt increases were observed in the embayment. Table II shows the results of cruises made before and after the first occurrence of leeches in the UB. Significant increases in total numbers, mean length, and length of the largest mature *N. americana* at UB stations 1 and 2 on 17 December 1975, coincided with the first occurrence of leeches in the UB since the previous spring. A similar but less distinct pattern of recurrence of large mysids and leeches was observed on 19 November 1976 (Table II).

A comparison of the abundance and size distribution of *M. borealis* at UB station 2 on four sampling dates during the 1977–78 infestation is shown in Table III. Leeches did not occur in any of the six replicate samplings on 12 October and supplementary sampling did not reveal leeches in the embayment until 21 December. At this time, leeches were associated with large overwintering mysids not found at any embayment stations the previous week. Collections on 23 December contained both juvenile and sexually mature leeches, but small adults dominated. Mean length and the length of the largest leeches had increased on 21 February and again on 24 April.

The seasonal pattern of occurrence of *M. borealis* on the extensive flats of Delaware Bay at Norburys Landing was similar to that in Hereford Inlet. Leeches

TABLE I

Mean monthly numbers of M. borealis *per 1000* N. americana *in epibenthic-sled collections made at stations 1–7 in Hereford Inlet from June 1975 to June 1977. Each value is based on 2–5 collections for which a ratio of total leeches to total mysids was determined. Dashes indicate that no samples were taken.*

Station	1	2	3	4	5	6	7
Jun 1975	0	0	0	0	0	—	—
Jul	0	0	<1	0	<1	0	<1
Aug	0	0	0	0	0	0	<1
Sep	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0
Dec	16	7	3	4	14	2	<1
Jan 1976	2	6	2	9	6	1	3
Feb	1	<1	4	1	1	<1	1
Mar	1	3	3	16	8	4	1
Apr	1	<1	7	3	7	4	5
May	4	<1	0	0	0	<1	<1
Jun	0	<1	0	0	<1	<1	4
Jul	0	0	<1	0	<1	<1	2
Aug	0	0	0	0	0	<1	0
Sep	0	0	0	0	0	0	<1
Oct	0	0	0	0	0	0	0
Nov	0	<1	<1	<1	<1	<1	<1
Dec	3	5	<1	1	6	—	—
Jan 1977	1	3	6	5	2	—	—
Feb	—	—	—	—	—	—	—
Mar	36	11	3	11	6	10	<1
Apr	—	—	—	—	—	—	—
May	1	0	0	4	4	1	1
Jun	<1	<1	1	1	0	0	1

TABLE II

Results of collections made at UB stations 1 and 2 during the period of leech recurrence in 1975 and 1976. L/M is the number of M. borealis *per 1000* N. americana *based on the ratio of total leeches per total mysids for each collection. nM is the total number of* N. americana. $\bar{X}$ *is the mean total length (mm) of mature* N. americana ± *standard deviation.* ^{X}min–^{X}max *is the range in total length (mm) of* N. americana. *Temperature is the same for both stations.*

		Station 1				Station 2			
Date	Temp.	L/M	nM	$\bar{X}$ ± SD	^{X}min–^{X}max	L/M	nM	$\bar{X}$ ± SD	^{X}min–^{X}max
3 Nov 1975	16°C	0	7080	9.6 ± 0.6	8.8–10.5	0	4169	9.9 ± 0.6	8.8–11.1
17 Nov 1975	12°	0	64	—	—	0	69	11.8 ± 0.8	10.9–13.0
2 Dec 1975	10°	0	105	10.9 ± 1.3	10.3–14.3	0	47	—	—
17 Dec 1975	8°	4	4885	14.5 ± 1.7	12.6–17.4	1	4200	15.3 ± 1.7	12.8–17.6
16 Jan 1976	3°	36	2082	14.7 ± 1.7	12.8–17.8	9	956	15.8 ± 1.9	13.2–17.9
25 Oct 1976	14°C	0	15325	10.5 ± 0.6	9.2–11.1	0	20832	10.5 ± 0.9	9.5–11.8
3 Nov 1976	9°	0	2936	10.3 ± 0.4	9.9–10.9	0	3198	10.5 ± 0.6	9.0–11.6
19 Nov 1976	7°	0	351	12.0 ± 1.0	10.7–13.4	1	6364	11.3 ± 1.3	9.7–14.1
6 Dec 1976	4°	3	10220	13.0 ± 0.6	11.3–14.1	5	15480	13.2 ± 0.6	12.4–14.1
6 Jan 1977	1°	1	8424	13.0 ± 0.9	10.1–16.4	3	12416	12.4 ± 1.3	10.3–14.1

were associated with *N. americana* during the coldest months and disappeared by early summer. In March, large leeches were attached to large mysids and few juveniles of either species were collected. After the peak brood release and die-off of large overwintering mysids in mid-April, few large leeches were collected. By early May, some large leeches and mysids remained, but both populations were dominated by very small individuals. Samples taken in mid-May yielded thousands of juvenile mysids (<5 mm) heavily infested with very small, apparently newly hatched leeches (<3 mm). Early June collections showed young mysids still abundant, but leeches virtually absent. No leeches were collected at temperatures higher than 21°C.

In the laboratory, *M. borealis* copulated and deposited cocoons from January to May (5–21°C), but the most intense activity was in March and April at 15°C. Leeches copulated while attached to mysid hosts. Adult leeches left their hosts to deposit their 0.5 mm cocoons on the seams of container walls and, in some cases, in depressions on the surfaces of sand grains. All leeches died within a few days after depositing cocoons. Increasing water temperature induced groups of cold-acclimated leeches to deposit cocoons within 10 days. Cocoons hatched in about

TABLE III

Results of four series of replicate collections at UB station 2 during the 1977–78 infestation of M. borealis. *N is the number of replicate tows. L/M is mean number of* M. borealis *per 1000* N. americana ± *standard deviation (coefficient of variation). The ratio is based on total leeches per total mysids determined for each replicate.* $\bar{Y}$ *is the mean length of* M. borealis ± *standard deviation.* ^{Y}min–^{Y}max *is the range in total length of* M. borealis. *% JUV is the percentage of the sample population that was less than 3 mm in length.*

	T°C	S (‰)	N	L/M ± SD (CV)	$\bar{Y}$ ± SD	^{Y}min–^{Y}max	% JUV
12 Oct 1977	16.1	30.1	6	0	—	—	—
23 Dec 1977	5.0	29.8	7	11 ± 2 (18%)	4.6 ± 0.8	2.0–6.2	1
21 Feb 1978	3.1	30.6	6	5 ± 1 (20%)	6.1 ± 1.0	2.3–8.4	6
24 Apr 1978	10.4	30.1	6	23 ± 4 (17%)	8.3 ± 1.1	2.3–10.1	14

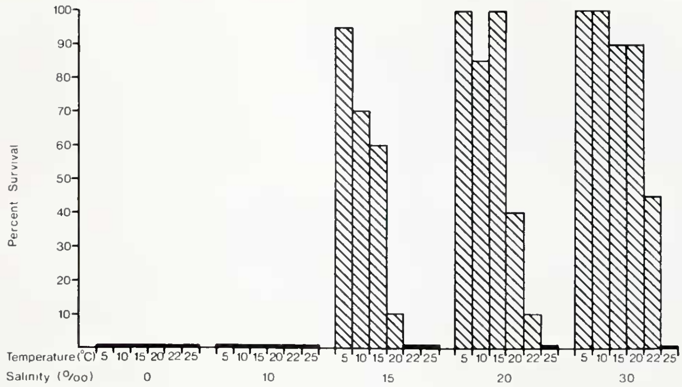

FIGURE 3. Mean values for the survival of adult *Mysidobdella borealis* in 30 combinations of temperature and salinity after 10 days exposure.

4 weeks at 20°C and in about 14 weeks at 7°C. We did not collect cocoons in the wild. Juvenile leeches (1.8–2.2 mm) usually attached themselves to *N. americana* within hours of emerging from cocoons. No young attached leeches survived more than 8 days at 20°C, but some juveniles remained attached to refrigerated mysids (7°C) for almost 6 months. These leeches were 2.7–4.4 mm in length when the experiment ended in late November.

Laboratory experiments indicated that *M. borealis* was intolerant of low salinities and high temperatures (Fig. 3). All leeches died in test salinities of 0 and 10‰ at all temperatures, and at 25°C at any salinity. Leeches survived best in combinations of high salinity and low temperature; *M. borealis* maintained below 10°C and at 30‰ in the laboratory usually survived for months.

DISCUSSION

The marine leech, *M. borealis*, suddenly occurred in sled collections in the salt marsh embayment at Hereford Inlet, New Jersey, each winter and persisted until early summer. The mysid host, *N. americana*, was ubiquitous in the major waterways throughout the year, but leeches were not associated with warm-water mysid populations. In New Hampshire, *M. borealis* was found only from December through March even though mysids were present all year (Burreson and Allen, 1978). Similar distributions of the leech and mysid were found in Barnegat Bay, New Jersey, where *M. borealis* occurred in 65 out of 307 samples from November 1975 to June 1976, but did not occur in any of the 224 collections taken from July through October (Sandine *et al.*, 1977).

The occurrence of leeches from late fall to early summer and their virtual absence during the warmest months has been reported for many temperate species (Thompson, 1927; Hoffman, 1955; Becker and Katz, 1965; Gibson and Tong, 1969; Halvorsen, 1971 and 1972; Sawyer and Hammond, 1973). Two alternative explanations for the warm-season absence of the leeches can be considered: (1) Life history patterns and behavior may enable summer populations to remain inconspicuous until the fall or (2) local populations die or migrate from the study area, then reappear in the fall. Sawyer and Hammond (1973) provide an example of the first alternative in their suggestion that *Calliobdella carolinensis* Sawyer and

Chamberlain embryos and juveniles escape detection during their slow summer development. Gibson and Tong (1969) reported that cocoons of *Oceanobdella blennii* (Knight-Jones) were capable of oversummering, so that reproductive structures deposited in the spring hatched 7 or 8 months later. In the case of *M. borealis* in Hereford Inlet, however, the second alternative must be considered.

When *M. borealis* was first collected in the embayment each winter, both juveniles and sexually mature individuals were present. Young leeches emerged from cocoons at about 2 mm and, if the small leeches in these collections originated from an oversummering population in the embayment, either the cocoons took a minimum of 6 months to hatch, or young hatched in the summer did not grow at all. Cocoons deposited in the laboratory hatched in less than 1 month at 20°C, and the juvenile leeches which emerged died within 8 days at this temperature. Laboratory experiments indicated that both juvenile and adult leeches were intolerant of warm temperatures and could not survive in the embayment at temperatures characteristic of the area from May to November.

Populations of *M. borealis* appeared to be introduced to the embayment each winter with an inshore migration of mysid hosts. As water temperatures decreased to about 10°C each fall, leeches and large mysids appeared in collections outside of Hereford Inlet. During the next 1–2 weeks, leeches appeared in the UB. Their recurrence coincided with major changes in the abundance and length frequency structure of the resident mysid population. Changes in the population structure of the mysids could not be explained by the growth of mysids already present in the UB, because the growth rate of *N. americana* at 10°C is about 1.0 mm/month (Pezzack and Corey, 1979) and the mean length of mysids collected in the UB increased by 3.6 mm between 2 and 17 December 1975. Increases in abundance and other evidence suggests a migration of large mysids from outside of the embayment (Allen, 1978).

Seasonal migrations of shallow water mysids have been reported from Europe (Tattersall, 1938; Vorstman, 1951; Holthuis, 1954; Kinne, 1955; Mauchline, 1967; and Hesthagen, 1973), South America (Almeida Prado, 1973), Australia (Hodge, 1963), and Russia (Zmudzinski, 1967). Migrations of *N. americana* have not been reported, but seasonal changes in distribution have been suggested by Black (1956), Hulburt (1957), and Herman (1963). Amaratunga and Corey (1975) described seasonal migrations of *Mysis stenolepis* in Passamaquoddy Bay, Canada, and the presence of *M. borealis* with this mysid host in shallow water during the summer may be related to the migration of the mysid from deep overwintering areas (Burreson and Allen, 1978).

M. borealis has been reported from the mysid, *Mysis oculata*, in the White Sea near Russia (Selensky, 1927), the Kara Sea and Aleutian Islands (Vasileyev, 1939), and Greenland (Epshtein, 1961) where cold, high salinity waters prevail. The seasonal occurrence of *M. borealis* as far south in the western North Atlantic as the shallow coastal areas of New Jersey and Delaware Bay is probably regulated by water temperature. Leeches which suddenly appear in the embayment each winter probably originate from a population associated with *N. americana* in deeper ocean areas. *N. americana* has been collected near the edge of the continental shelf at 232 m (Wigley and Burns, 1971) and is abundant in the ocean off New Jersey where water temperatures are always less than 20°C. Thus, migrating mysids function as dispersal agents for *M. borealis* by extending its distribution to coastal embayments and estuaries, but the inability of this arctic species to survive summer conditions prevents *M. borealis* from becoming a permanent member of the temperate salt marsh fauna.

ACKNOWLEDGMENTS

We thank Dr. Eugene M. Burreson for valuable discussion about the interaction and Dr. Sidney S. Herman for support in the field and laboratory studies at The Wetlands Institute. The financial support of the J. S. Noyes Foundation and the Huber Foundation is gratefully acknowledged.

LITERATURE CITED

ALLEN, D. M. 1978. *Population dynamics, spatial and temporal distributions of mysid crustaceans in a temperate marsh estuary.* Ph.D. Dissertation, Lehigh University, Bethlehem, Pennsylvania. 157 pp.

ALMEIDA PRADO, M. S. DE. 1973. Distribution of Mysidacea (Crustacea) in the Cananeia Region. *Biol. Zool. Biol. Mar., N. S.* **30:** 395–417.

AMARATUNGA, T., AND S. S. COREY. 1975. Life history of *Mysis stenolepis* Smith (Crustacea, Mysidacea). *Can. J. Zool.* **53:** 942–952.

BECKER, C. D., AND M. KATZ. 1965. Distribution, ecology, and biology of the salmonid leech *Piscicola salmositica* (Rhyncobdellidae: Piscicolidae). *J. Fish. Res. Bd. Can.* **22:** 1175–1195.

BLACK, W. F. 1956. *The Mysidacea of the Bras d'Or Lakes.* Ph.D. Dissertation. McGill University, Montreal, Canada. 210 pp.

BURRESON, E. M., AND D. M. ALLEN. 1978. Morphology and biology of *Mysidobdella borealis* (Johansson) comb. n. (Hirudinea: Piscicolidae) from mysids in the western North Atlantic. *J. Parisitol.* **64:** 1082–1091.

DANIELS, B. A., AND R. T. SAWYER. 1975. The biology of the leech *Myzobdella lugubris* infesting blue crabs and catfish. *Biol. Bull.,* **148:** 193–198.

DUKINA, V. V., V. S. TVOROVSKII, AND V. M. EPSHTEIN. 1974. The finding of the fish leech *Caspiobdella fadejevi* on shrimps (mysids) in the Pechenezh Reservoir. *Zool. Zh.,* **53(9):** 1413–1414.

EPSHTEIN, V. M. 1959. On the taxonomy, mode of life and origin of the endemic Baikal leech *Trachelobdella torquata* (Grube). *Doklady Biol. Sci.* **125:** 935–937.

EPSHTEIN, V. M. 1961. A review of the fish leeches (Hirudinea: Piscicolidae) from northern seas of SSSR. *Doklady Biol. Sci.* **141:** 1121–1124.

GIBSON, R. N., AND L. J. TONG. 1969. Observations on the biology of the marine leech *Oceanobdella blennii. J. Mar. Biol. Assoc. U. K.* **49:** 433–438.

HALVORSEN, O. 1971. Studies of the helminth fauna of Norway, XIX. The seasonal cycle and microhabitat preference of the leech, *Cystobranchus mammillatus* (Malm 1863) parasitizing burbot, *Lota lota* (Linnaeus). *Norw. J. Zool.* **19:** 177–180.

HALVORSEN, O. 1972. Studies of the helminth fauna of Norway, XXX. Seasonal cycles of fish parasites in the River Glomma. *Norw. J. Zool.* **20:** 9–18.

HERMAN, S. S. 1963. Vertical migration of the opossum shrimp, *Neomysis americana* (Smith). *Limnol. Oceanogr.* **8:** 228–238.

HESTHAGEN, I. H. 1973. Diurnal and seasonal variations in the near-bottom fauna—the hyperbenthos—in one of the deeper channels of the Kieler Bucht (Western Baltic). *Kiel. Meeresforsch.* **XXIX(2):** 116–140.

HODGE, D. 1963. The distribution and ecology of the mysids in the Brisbane River. *Queensland Univ., Brisbane Dept. Zool., Papers* **2:** 91–104.

HOFFMAN, J. 1955. Quelque characteres ethologiques de la Piscicolidee: *Cystobranchus respirans* Troschel. *Archiv. Inst. Grand-Ducal de Luxembourg.* N. S. **22:** 223–235.

HOLTHUIS, L. B. 1954. Mysidacea. Pp. 213–219 in L. F. de Beaufort, Ed., *Veranderung in de Flora en Fauna der Zuidersee.* Nederlandse dierkundige Vereniging den Helder, Netherlands.

HULBURT, E. M. 1957. The distribution of *Neomysis americana* in the estuary of the Delaware River. *Limnol. Oceanogr.* **2:** 1–11.

KINNE, O. 1955. *Neomysis vulgaris* (Thompson): eine autokologisch-biologische Studie. *Biol. Zentralbl.* **74:** 160–202.

MAUCHLINE, J. 1967. The biology of *Schistomysis spiritus* (Crustacea, Mysidacea). *J. Mar. Biol. Assoc. U. K.* **47:** 383–396.

MEYER, M. C., AND A. A. BARDEN. 1955. Leeches symbiotic on Arthropoda, especially decapod Crustacea. *Wasmann J. Biol.* **13:** 297–311.

MOORE, J. P., AND M. C. MEYER. 1951. Leeches (Hirudinea) of Alaska and adjacent waters. *Wasmann J. Biol.* **9:** 11–77.

Pezzack, D. S., and S. Corey. 1979. The life history and distribution of *Neomysis americana* (Smith) (Crustacea, Mysidacea) in Passamaquoddy Bay. *Can. J. Zool.* **57:** 785–793.

Sandine, P. H., K. A. Tighe, and H. W. Hoffman. 1977. Entrainment. Pp. 3–26 in T. R. Tatham, P. H. Sandine, R. P. Smith, H. W. Hoffman, K. A. Tighe, and D. L. Thomas. *Preliminary Final Report of Ecological Studies for the Oyster Creek Generating Station.* Ichthyological Assoc., Inc., Absecon, New Jersey.

Sawyer, R. T., and D. L. Hammond. 1973. Observations on the marine leech *Calliobdella carolinensis* (Hirudinea: Piscicolidae) epizootic on the Atlantic menhaden. *Biol. Bull.* **145:** 373–388.

Sawyer, R. T., and M. G. White. 1969. A new genus and species of marine leech, *Glyptonotobdella antarctica*, from an Antarctic isopod. *Br. Antarct. Surv. Bull.* **22:** 1–14.

Selensky, W. D. 1923. *Crangonobdella murmanica* n.g., n.sp., ein auf *Sclerocrangon schmarotzende* Ichthyobdellidae. *Zool. Jahrb.* **46:** 397–488.

Selensky, W. D. 1927. On a new Ichthyobdellidae (*Mysidobdella oculata* n.gen. n.sp.) a parasite on Crustacea. *Proc. 2nd Cong. of Zoologists, Anatomists, and Histologists of USSR,* **2:** 32–33. (In Russian).

Tattersall, W. M. 1938. The seasonal occurrence of mysids off Plymouth. *J. Mar. Biol. Assoc. U. K.* **23:** 43–56.

Thompson, D. H. 1927. An epidemic of leeches on fishes in Rock River. *Bull. Ill. State Nat. Hist. Surv.* **17:** 195–201.

Vasileyev, E. A. 1939. The Ichthyobdellidae of the Far East. *Trudy Karel. Gos. Pedagog. Inst., Ser. Biol.* **1:** 25–66.

Vorstman, A. G. 1951. A year's investigation into the life cycle of *Neomysis vulgaris* Thompson. *Verhandlungen der Internationalen Vereinigung fur Theoretische und angewandie Limnologie* **II:** 437–445.

Wigley, R. L., and B. R. Burns. 1971. Distribution and biology of mysids (Crustacea, Mysidacea) from the Atlantic coast of the United States in the NMFS Woods Hole collection. *U. S. Fish. Wildl. Serv. Fish. Bull.* **69:** 717–746.

Zmudzinski, L. 1967. Seasonal migrations of coldwater fauna in the Gdansk Bay. *Cons. Perm. Int. Explor. Mer, 2(2), Ann. Biol.* **21:** 65–67.